

A Study on Spatial Power Combiner using a Wideband Balanced Lens Amplifier

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1. Introduction

In recent years, as the operating frequency of semiconductor solid-state devices increases, the size of the devices and their power handling capacity are reduced. In order to provide the advantages of a solid-state technology for moderate power levels at millimeter-wave frequencies, multiple solid-state components must be combined using corporate combining structures. However spatial power combining provides more RF efficiency by combining power in free space than via transmission lines in corporate combining structures. So recently, some researches have been studied on the quasi-optical and spatial power combining structures [1][2].

Among various spatial power combining technique, lens amplifier increases the efficiency and gain by focusing beam pattern and reducing losses due to diffraction [3][4].

In this paper, we propose the 1D and 2D lens amplifiers which are operating for C-band and composed of wideband printed dipole antenna, balanced delay lines, and balanced amplifiers. The lens amplifiers provide simple structure, low-cost, and wide bandwidth because they are planar and balanced structure. First, we design the each component of the lens amplifier, and then implement 1D and 2D lens amplifiers by connecting them.

2. Design of lens amplifier

The geometry of the proposed lens amplifier which is composed of lens antenna and amplifier is shown in Fig. 1(a). In case the focal points are placed on z-axis ($\theta_0 = 0, \phi_l = 0$), the length of delay lines is calculated by (1) [5].

$$W = F + W_0 - [F^2 + \rho^2]^{1/2} \quad (1)$$

In equation (1), we choose the focal length F of 25 cm and the center delay line length W_0 of 30 cm. And the antenna spacing in the input and output antenna array is set to be 0.8λ considering grating lobe, the locations of the input and output antenna are same for simplifying the structure of lens amplifier. Fig. 1(b) shows typical circuit diagram of lens amplifier. This is consist of 4 components, which are shown in Fig. 2, such as (a) input vertically polarized fat dipole antenna, (b) output horizontally polarized fat dipole antenna, (c) CPS structure balanced delay line, and (d) balanced amplifier. The length of the input and output dipole antennas is designed about $\lambda/2$ long. These antennas must have the width to length ratio(W/L) of approximately 0.9~1.1 and the gap(G) of about 0.1L to obtain wideband characteristics [6][7]. The parameters of the designed components are summarized in Table 1. The input and output

antennas have 20.5 % bandwidth and 2.89 dBi gain, 24 % bandwidth and 4.82 dBi gain, respectively. The balanced amplifier is designed by using Gali-1 MMIC amplifier module which is matched to 50Ω . And it has flat gain characteristics with the maximum gain of 8.5 dB at 6 GHz, stable phase difference, and the stable stability factor greater than 1 over designed frequencies. In case of the longest balanced delay line, it has S21 of below -0.2 dB and S11 of below -10 dB over 4 ~ 8 GHz.

3. Simulated and experimental results

Simulated results of absolute gain versus frequency for the proposed 1D, 2D lens amplifiers are presented in Fig. 3, respectively. Absolute gain means an increase in the effective radiated power of a source due to using lens amplifier in a free-space power measurement [3]. An CST 3D EM simulator for analysis of the antenna, and delay lines and an Agilent circuit simulator for analysis of the balanced amplifier are used to calculate the gain of the lens amplifiers. The 1D lens amplifier with linear 5×1 elements is compared with 5×1 antenna array amplifier (AAA) which doesn't have delay lines. Also the 2D lens amplifier with square shaped 5×5 array is compared with 5×5 AAA. Fig. 3 shows that the designed 1D and 2D lens amplifiers have improved absolute gain, about 4 dB higher than AAA at 6 GHz.

Fig. 4 shows the fabricated 5×1 1D lens amplifier composed of input and output polarized dipole antenna array, balanced delay line array, and balanced amplifier array. The antenna is built on a substrate with relative permittivity $\epsilon_r = 2.5$ and dielectric thickness $h = 1.6$ mm, and the delay lines and the amplifiers are built on a substrate with $\epsilon_r = 4.5$, $h = 1.6$ mm. The 5×5 2D lens amplifier is under fabrication. Using the measurement technique reported in [3], the absolute gain of the fabricated 1D lens amplifier is measured. The measured absolute gain versus frequency for the proposed design is presented at Fig. 5(a). Fig. 5(a) shows that the proposed lens amplifier provides the wide 3-dB bandwidth of 1.31 GHz (5.21 GHz – 6.52 GHz) and has a peak absolute gain of -0.9 dB. This result is similar to the simulated result. But the gain difference between measured and simulated result is getting bigger above 6 GHz. The reason is because the effect of conductor and dielectric losses of the lens amplifier is not considered in simulation. The near-field pattern is measured by using near-field measurement system of NSI corporation, as shown in Fig. 5(b), the pattern is focused at the focal length of 25 cm.

4. Conclusions

In this paper, a new lens amplifier with wideband printed fat dipole antenna, balanced delay lines, balanced amplifiers is proposed as a improved spatial power combiner. Because of the isolation between the input and output antenna, and the good stability over wide bandwidth of the balanced amplifier, the lens amplifier has wide 3-dB bandwidth characteristics. Also It provides a higher absolute gain than conventional AAA due to lens focusing even though the number of elements are the same in both. The proposed 5×1 1D lens amplifier provides -0.5 dB of absolute gain at 6 GHz and 1.31 GHz of 3-dB bandwidth. The simulation result of 5×5 2D lens amplifier is 12 dB of absolute gain and 1.23 GHz of 3 dB bandwidth.

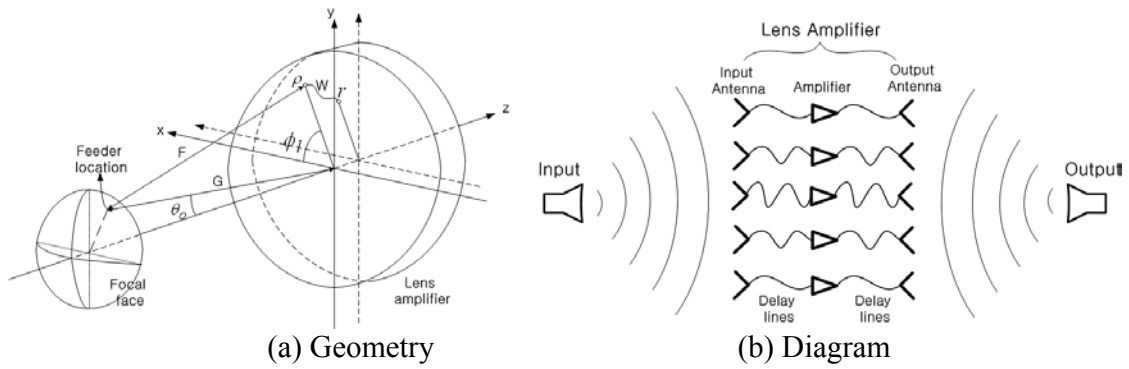


Fig. 1. Lens amplifier

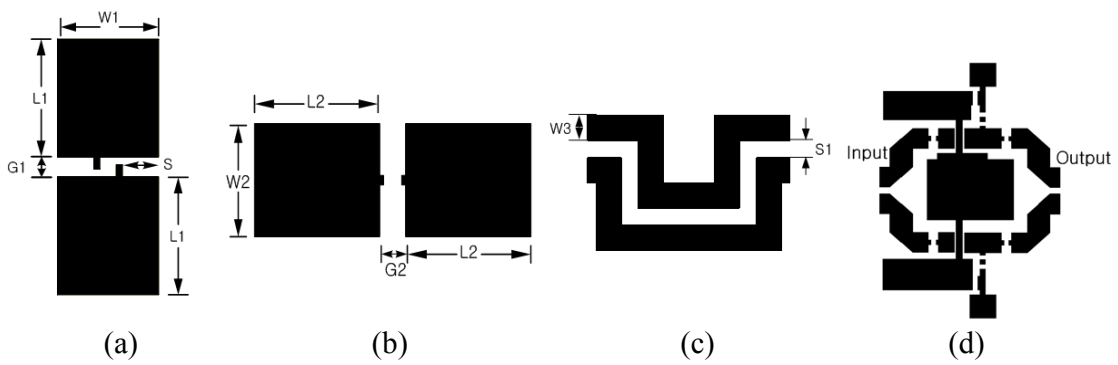
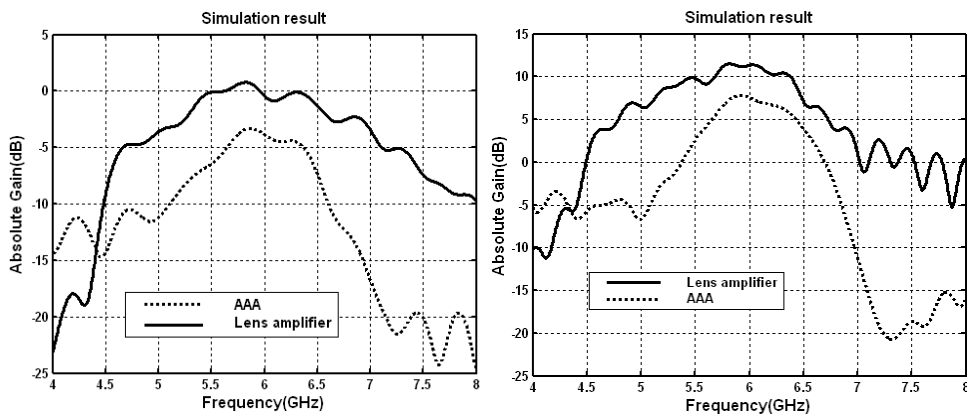


Fig. 2. Components of the lens amplifier

Table. 1. Designed parameters of the components

Parameter	Length (mm)	Parameter	Length (mm)	Parameter	Length (mm)
W1	8.5	W2	9	W3	1
L1	12.03	L2	11.73	S	3.05
G1	2	G2	2	S1	0.8



(a) 1D lens amplifier (b) 2D lens amplifier
Fig. 3. Simulation results of the 1D, 2D lens amplifier

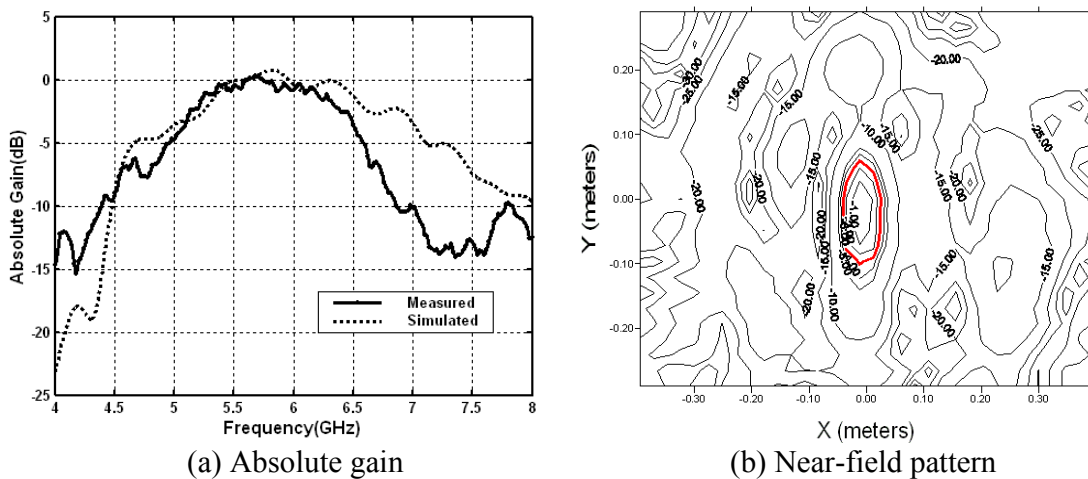
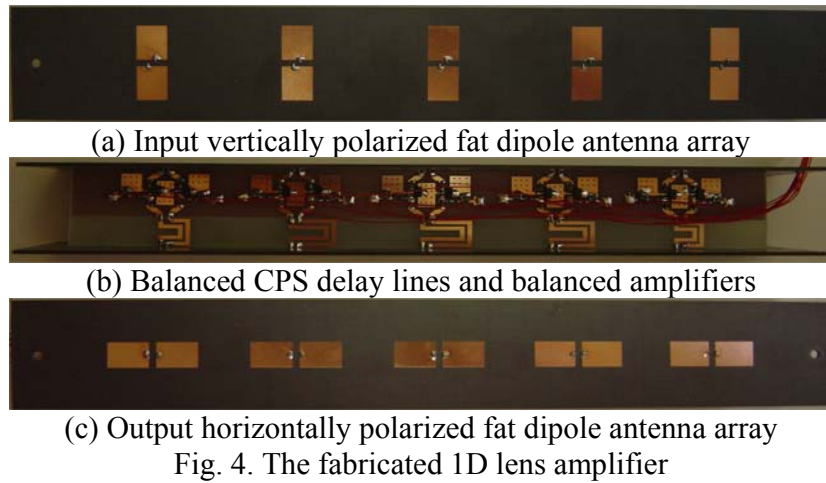


Fig. 5. The measured results of the fabricated 1D lens amplifier

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